

S1C17 Family Application Note
S1C17M02/M03
Application Note

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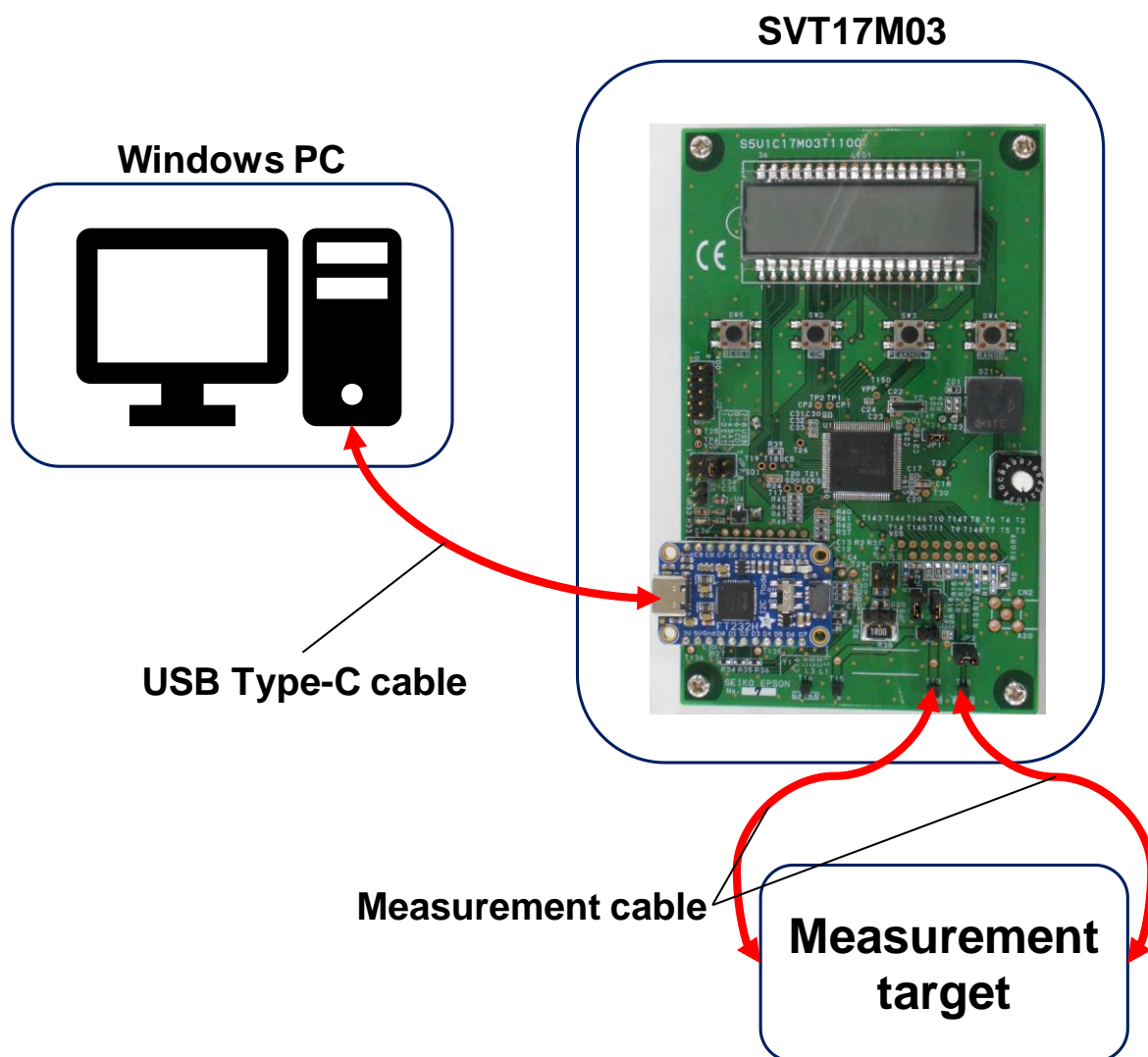
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1. Overview

The Reference Solution for Seiko Epson Digital Multimeters (DMMs) is a solution package for designing DMMs using Seiko Epson's microcontroller S1C17M03.

This package consists of the reference board S5U1C17M03T1100(SVT17M03), reference software, and application note (this document), and is provided to enable the efficient design of DMMs with a small number of man-hours.

1.1. System configuration



Note: Please provide your own USB cable, and Measurement cable.
Figure 1.1-1 Hardware configuration

Overview

Table 1.1-1 List of Offerings

	Items	Contents	Descriptions
1	Hardware	S5U1C17M03T(SVT17M03)	Evaluation board
2	Software	S1C17M02 M03 demo software vX.X.zip*	Software package
3	Document	This document	Application note

*X: Software version

Table 1.1-2 Contents of software package

	Items	Descriptions
1	s1c17m02_m03_application_verX.X* └─ s1c17m02_m03_application_gnu17v3	Project folder
2	DmmTools_X.XX* ├─ DmmEvalTool.exe └─ dll files	Communication software for PC
3	Dmm_readme_en.txt Dmm_readme_jp.txt	Readme file in English Readme file in Japanese
4	License_e.txt	Software License Agreement
5	S5U1C17M03Txxxx_jumper connections_en.xlsx* S5U1C17M03Txxxx_jumper connections_jp.xlsx*	Jumper configuration table in English Jumper configuration table in Japanese

*X, x: Software version

2. System resources

2.1. Microcontroller resources

Table 2.1-1 Microcontroller resources

Items	Contents
CPU	S1C17M03
System clock	3.2MHz (Internal OSC3)

2.2. Functional specification description

PPORT	P07 of PPORT is used for output as a timing signal for SPI communication. P40, P41, P42, and P43 are used as inputs for rotary switches. P44, P45, and P46 are used as tactile switch inputs.
DMM controller	Used for measurement as a DMM.
LCD4B	Controls the LCD for display.
SNDA	Used to play beep sound by a buzzer.
SPIA Ch.0	Assign P00 of PPORT to SCS, P01 to SDO, and P03 to SCK with using UPMUX. Used for communication with PC.
T16 Ch.0	Used for mode name display and DMM controller timeout.
T16 Ch.1	Used for polling scan of various switches and LCD display switching.
T16B_DMM Ch.0	Frequency calculation: Used for the frequency measurement period.
T16B_DMM Ch.1	Frequency calculation: Used to capture the measurement waveform signal during the frequency measurement period. Assign the tout output of T16B_DMM Ch.0 to CAP.
T16B_DMM Ch.2	Frequency calculation: Used to count during one cycle of the measurement waveform. Assign the measurement waveform pulse signal to CAP.
SVD4	Used to detect the battery level.
UART3 Ch.0	Assign P03 of PPORT to SIN and P02 to SOUT with using UPMUX. Used for communication with PC.
Clock	OSC3 (internal oscillation: 3.2MHz) is used as the system clock. OSC1 is used to drive LCD4B, SNDA, T16 Ch.0, T16B_DMM Ch.0, T16B_DMM Ch.2, and SVD4. OSC3 is used to drive the DMM controller, and T16 Ch.1.

3. Operation description

3.1. Operation overview

This system uses the DMM controller and 16-bit PWM timer for DMM in the S1C17M03 on the SVT17M03 to perform measurements in the corresponding measurement range. Although this software can use all measurement settings available in the S1C17M03, the actual measurement is limited to the measurement modes available due to the limitations of the SVT17M03. Please refer to the separately published manual “S5U1C17M03T Manual” for details.

Table 3.1-1 Measurement modes and ranges available in this software

Measurement modes	Measurement ranges
DC voltage	600 mV / 6 V / 60 V / 600 V / 1,000 V
AC voltage	600 mV / 6 V / 60 V / 600 V / 1,000 V
DC current	600 uA / 6 mA / 60 mA / 600 mA / 6 A / 10 A
AC current	600 uA / 6 mA / 60 mA / 600 mA / 6 A / 10 A
Resistance (CC-method)	600Ω / 6kΩ / 60kΩ / 600kΩ / 6MΩ / 60MΩ
Resistance (CV-method)	600Ω / 6kΩ / 60kΩ
Continuity check	CV / CC
Capacitance (CC-method)	1uF / 10uF / 100uF / 1,000uF
Capacitance (CV-method)	10nF / 100nF
Diode VF	-
AC voltage and frequency	6V
AC current and frequency	6mA
Internal temperature	-

The measured results will be output through the following methods.

- Displayed on the LCD panel on the SVT17M03
- Transmission to a PC via UART or SPI communication*
- Play the continuity check buzzer on the SVT17M03

*The internal temperature measurement does not display the result on the LCD panel but outputs the measurement register value through serial communication.

3.2. Measurement configuration switching

When performing measurement operations as a DMM, the user can change the measurement mode and other settings and start transmitting measurement results via serial communication by operating the tactile switches (SW2 to SW5) and rotary switch (SW1) mounted on the SVT17M03.



Figure 3.2-1 Tactile switches (SW2 to SW5)



Figure 3.2-2 Rotary switch (SW1)

Table 3.2-1 Operation when each switch is pressed

Switches	Operations
SW1	Measurement mode switching
SW2	Start/Stop communication mode
SW3	Peak-hold configuration switching
SW4	Measurement range switching
SW5	Perform a hardware reset

3.2.1. Measurement mode switching

At initial startup and during measurement or communication mode, rotating the rotary switch (SW1) on the SVT17M03 sets the DMM controller's measurement mode setting to the value corresponding to the number on the switch. When switching, the name of the target measurement mode is displayed on the LCD on the SVT17M03 for 1 second. Also, the measurement range is set to the default range.



Figure 3.2.1-1 LCD screen when switched to DC voltage measurement

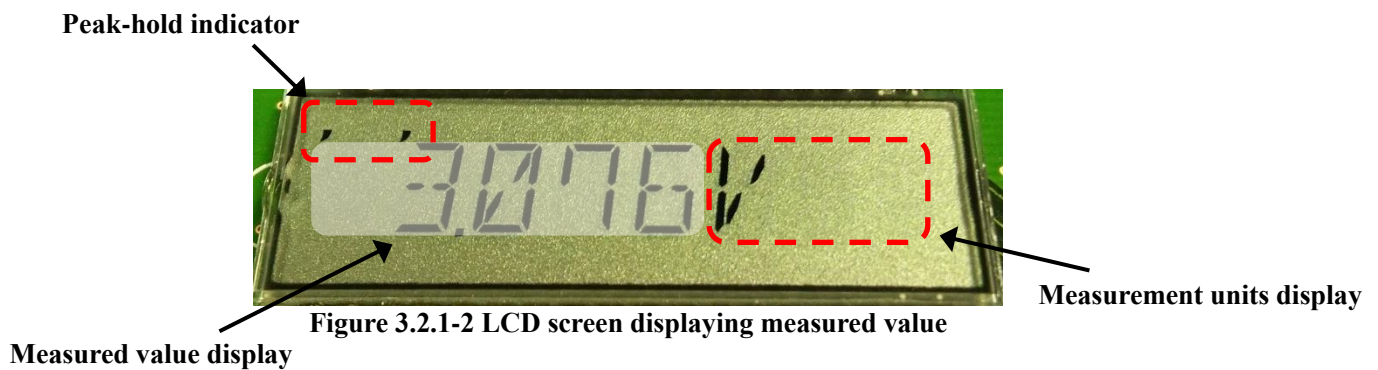
Operation description

Table 3.2.1-1 SW1 number and corresponding measurement mode

SW1 #	Measurement modes	Default ranges	Mode names
0	DC voltage	6V	DCV
1	AC voltage	6V	ACV
2	DC current	6mA	DCI
3	AC current	6mA	ACI
4	Resistance (CC-method)	600Ω	OHM CC
5	Resistance (CV-method)	600Ω	OHM CV
6	Continuity check	CV	CONT
7	Capacitance (CC-method)	1uF	CAP CC
8	Capacitance (CV-method)	10nF	CAP CV
9	Diode VF	-	DIODE
A	AC voltage and frequency	6V	FREQ ACV
B	AC current and frequency	6mA	FREQ ACI
C	Internal temperature	-	TEMP

Note: Unused number is selected, no measurement is taken and "NOFUNC" is displayed on the LCD.

After the measurement mode is displayed, the measurement operation as a DMM is performed. The measured value is displayed on the LCD on the board as shown below. In the case of continuity check mode, the buzzer on the board plays when continuity is detected.



3.2.2. Peak-hold configuration switching

Pressed each time the tactile switch (SW3) in the measurement mode, the peak hold function can be toggled one level at a time, and the enabled setting can be checked from the “ ” indicator in the upper left corner of the LCD screen.

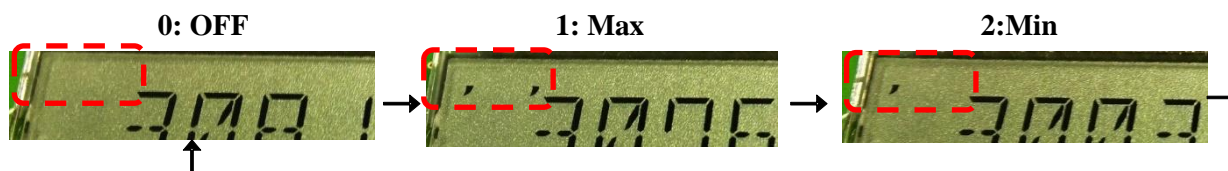


Figure 3.2.2-1 LCD display for peak-hold switching

3.2.3. Measurement range switching

Pressed each time the tactile switch (SW4) during measurement mode, the measuring range can be switched one step at a time within the settable range.

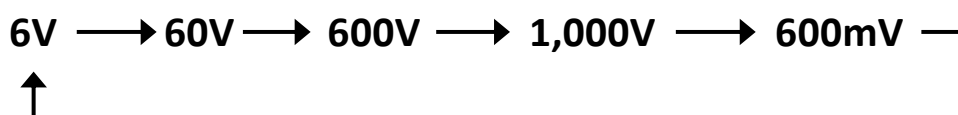


Figure 3.2.3-1 Example) Measurement range switching for DC voltage measurement

Operation description

3.3. Communication mode

Pressing the tactile switch (SW2) on the SVT17M03 while executing the measurement mode corresponding to the communication mode initiates the communication mode and places the device on standby for transmission of measurement results via serial communication. The communication mode is terminated when the specified number of measurement data is completed to be sent during the communication in progress mode or when the tactile switch (SW2) or rotary switch (SW1) on the board is rotated. During the communication mode, "COM" is displayed on the LCD.



Figure 3.3-1 LCD display during communication mode

3.3.1. Communication method

This software can use UART or SPI as the communication method. To change the communication method, the following description of the "s1c17m02_m03_application_gnu17v3" source code must be changed.

- When using UART communication
Comment out the following description in "src/mid_communication.h"
`#define COMMUNICATION_MODE_SPI`
- When using SPI communication
If the following description in "src/mid_communication.h" is commented out, uncomment it.
`#define COMMUNICATION_MODE_SPI`

3.3.1.1. UART communication

When the communication mode is started with UART communication enabled, the transmission of measurement results via UART begins.

- (1) Communications protocol

Table 3.3.1.1-1 UART communication protocol

Items	Setup values
Baudrate	230,400 bps
Data length	8 bit
Stop bit	1 bit
Parity	none
Flow control	none

(2) Operation check procedure

1. set the measurement settings for data communication using the rotary switch or tactile switches on the SVT17M03
2. connect the PC to the board with a USB Type-C cable
3. start terminal software (e.g., Tera Term) on PC and connect to SVT17M03
4. Press the tactile switch (SW2) on the board to start communication mode and send data
5. the terminal software displays the received data.

3.3.1.2. SPI communication

To communicate measurement data via SPI communication, it is necessary to operate “DmmEvalTool”, the PC communication software, at the same time as operating the SVT17M03. In this state, clicking the START button on the “DmmEvalTool” executes communication.

(1) DmmEvalTool

DmmEvalTool is included in the software package. Double-click “DmmEvalTool.exe” under the “DmmTools_X.XX” (X: version) folder in the package to start it.

When DmmEvalTool is started, the following window will appear on the PC screen.

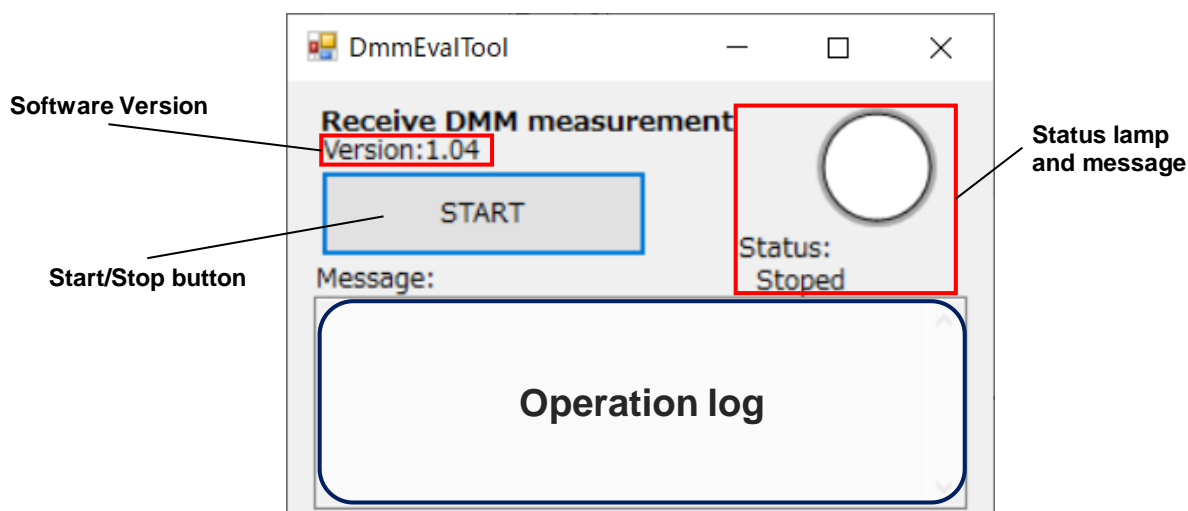


Figure 3.3.1.2-1 DmmEvalTool window

When communication is completed according to the method described below, DmmEvalTool creates a "Logs" folder in the same directory as the execution file and saves the measurement data inside the folder under the name "Output.csv".

The data format recorded in "Output.csv" is as follows. If you perform a measurement multiple times, the second and subsequent measurements are recorded and updated in the second and subsequent rows of "Output.csv".

Operation description

Table 3.3.1.2-1 Measurement data recording format

Rows	Contents
1	Number of measurements
2	Measurement mode
3	Measurement range
4	Peak-hold configuration
5~	Measurement data

(2) Communications protocol

Table 3.3.1.2-2 SPI communications protocol

Items	Setup values
Control	Slave
Data sequence	MSB first
SPI mode	Mode 3
Data length	8 bits

(3) Operation check procedure

1. set the measurement settings for data communication using the rotary switch or tactile switched on the SVT17M03
2. connect the PC to the board with a USB Type-C cable
3. start DmmEvalTool and connect to SVT17M03
4. Press the tactile switch (SW2) on the board to start the communication mode and put the board on standby for data transmission
5. click the START button on DmmEvalTool to start communication
6. when communication is completed, DmmEvalTool generates a CSV file of the received measurement data

3.3.1.3. SPI data transmission

In data communication using DmmEvalTool, this software modifies a part of the SPI communication protocol and communicates using a method unique to this software.

This software does not use the SDI signal in SPI communication, but only the SDO signal for one-way communication. Therefore, one port of GPIO output is used as a timing signal to inform the communication partner of the start and end of data communication. P07 is used as the GPIO output.

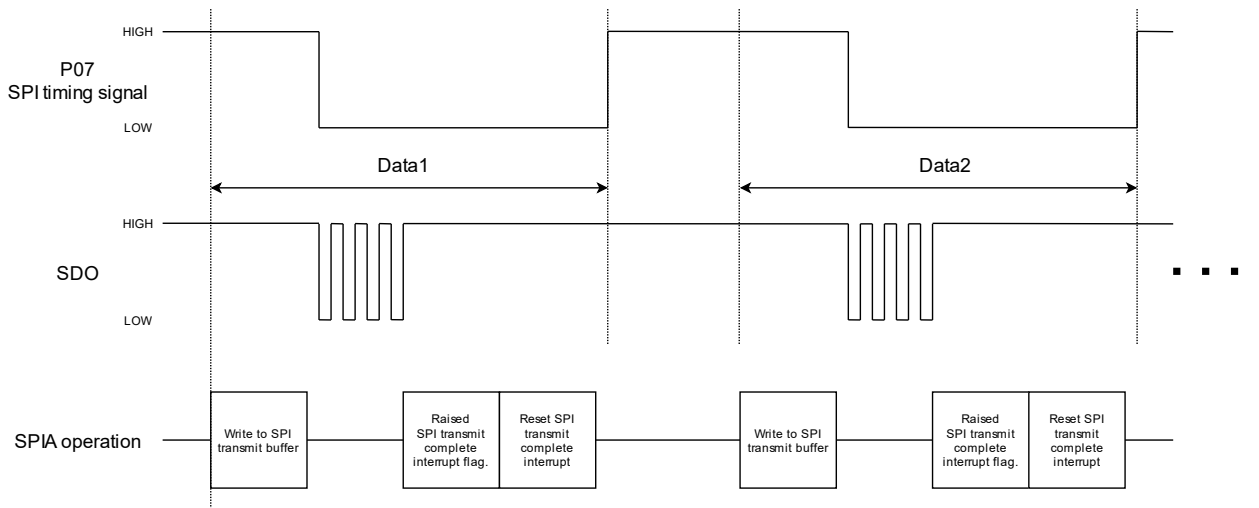


Figure 3.3.1.3-1 Data communication via SPI

3.3.2. Transmission data format

The data transmitted from SVT17M03 in the communication mode consists of three consecutive pieces of data: measurement mode data, measurement data, and communication termination data, and is transmitted using the following data format.

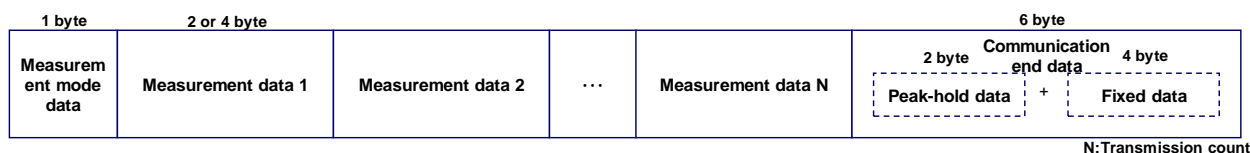


Figure 3.3.2-1 Communication data format

3.3.2.1. Measurement mode data

When the communication mode is initiated, one byte of measurement mode data is sent. The measurement mode data consists of the following data to identify measurement information. Each of the measurement range and measurement mode information that make up the measurement mode data corresponds to each measurement setting register value of the DMM controller.

Table 3.3.2.1-1 Measurement mode data format

Bit #	Contents
7	0
6:4	DSADC16CTL.RANGESEL[3:0] (Measurement range)
3:0	DSADC16CTL.FUNCSEL[3:0] (Measurement mode)

Operation description

3.3.2.2. Measurement data

After measurement mode data transmission is complete, measurement data is transmitted next. The measurement data consists of the measurement result register value or the calculated measurement value as shown below. For details on the measurement result register values, please refer to the “S1C17M02/M03 Technical Manual” published separately.

As mentioned above, measurement data is transmitted until the number of data specific to each measurement mode has been transmitted, the tactile switch (SW2) is pressed, or the rotary switch (SW1) is turned.

Table 3.3.2.2-1 Measurement data format

Measurement mode	Data length	Data type	Transmit data counts
DC voltage	2byte	Signed integer	500
AC voltage	4byte	Unsigned integer	250
DC current	2byte	Signed integer	500
AC current	4byte	Unsigned integer	250
Resistance (CC-method)	2byte	Signed integer	500
Resistance (CV-method)	2byte	Signed integer	500
Continuity check		Communication unsupported	
Capacitance (CC-method)	4byte	Single precision floating point	100
Capacitance (CV-method)	4byte	Single precision floating point	100
Diode VF	2byte	Signed integer	500
AC voltage and frequency	4byte	Single precision floating point	100
AC current and frequency	4byte	Single precision floating point	100
Internal temperature	2byte	Signed integer	500

3.3.2.3. Communication end data

When the specified number of measurement data is sent, or when the tactile switch (SW2) is pressed or the rotary switch (SW1) is turned, communication end data is sent and the communication mode is terminated.

The communication end data consists of 2 bytes of data related to the peak hold function and 4 bytes of fixed data, for a total of 6 bytes of data.

Table 3.3.2.3-1 Communication end data format

Peak-hold functions	Peak-hold data	Fixed data
Minimum value peak-hold	FF 0D	5A 96 96 5A
Maximum value peak-hold	FF 0E	5A 96 96 5A
OFF	FF 0F	5A 96 96 5A

3.4. Low battery mode

During the operation of this software, the low battery mode is initiated when the supply voltage supplied to the SVT17M03 falls below 2.2V and is detected by the Supply Voltage Detector (SVD4). In this mode, the supply of clock pulses to all other peripheral circuits except for the circuits necessary for the LCD is stopped, and the LCDs "LOW BATT" as shown in the figure below prompts the user to replace the batteries.

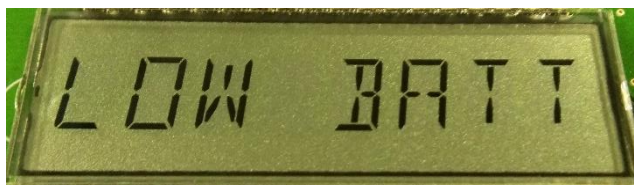


Figure 3.4-1 LCD display during low battery mode

4. Software description

4.1. Function blocks

This software consists of a driver layer that directly operates peripheral circuits, an application layer that realizes DMM operation, and a middle layer that serves as an interface between them.

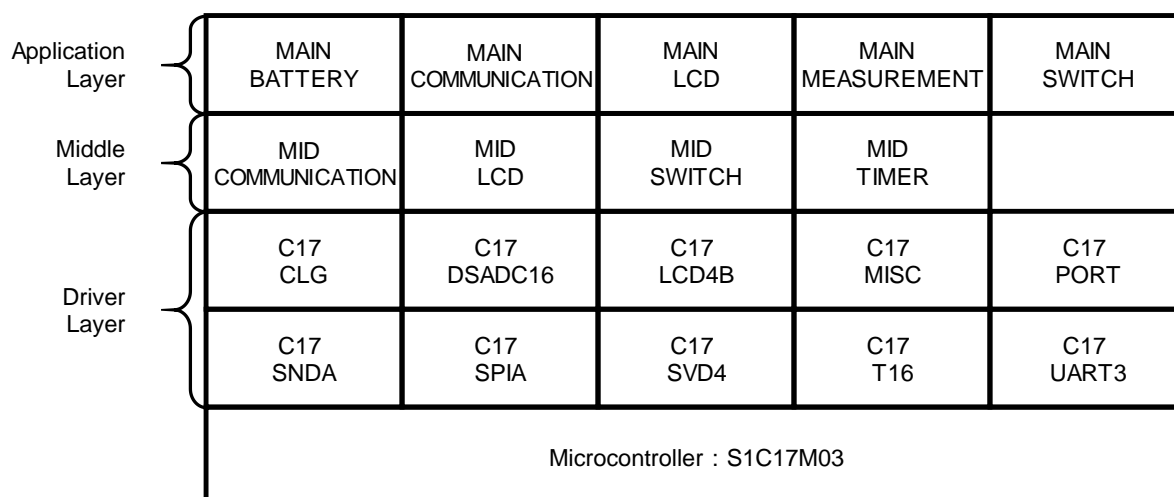


Figure 4.1-1 Function blocks

Table 4.1-1 Function block overview

Function blocks	Description
MAIN BATTERY	Low battery mode
MAIN COMMUNICATION	Communication mode
MAIN LCD	LCD display for various modes
MAIN MEASUREMENT	Measurement mode
MAIN SWITCH	Mode switching
MID COMMUNICATION	Communication interface
MID LCD	LCD interface
MID SWITCH	Switch interface
MID TIMER	Timer interface
C17 CLG	CLG driver
C17 DSADC16	DMM controller driver
C17 LCD4B	LCD4B driver
C17 MISC	MISC driver
C17 PORT	PPORT driver
C17 SNDA	SNDA driver
C17 SPIA	SPIA driver
C17 SVD4	SVD4 driver
C17 T16	T16 driver
C17 UART3	UART3 driver

4.2. Operation conceptual diagram

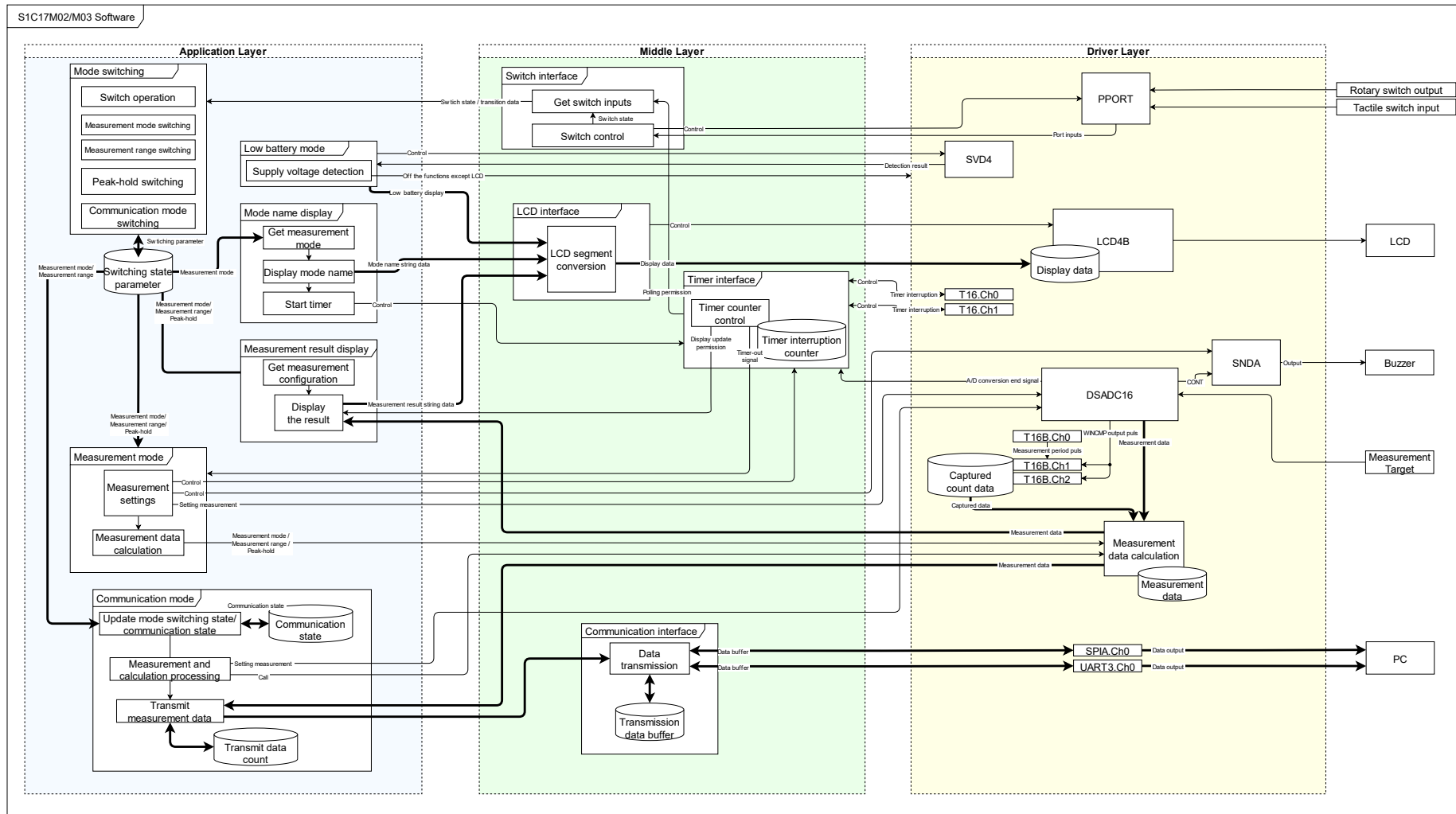


Figure 4.2-1 Software operation conceptual diagram

4.3. About s1c17m02_m03_application_gnu17v3

This section describes the “s1c17m02_m03_application_gnu17v3” software that enables operation as a DMM.

4.3.1. File structure(src/)

The prefix at the beginning of the file name indicates the application layer (main_), middle layer (mid_), and driver layer (c17_).

Table 4.3.1-1 Application layer files

File name	Functions
main_battery.c/h	Low battery mode program file
main_communication.c/h	Communication mode program file
main_lcd.c/h	LCD display for various modes program file
main_measurement.c/h	Measurement mode program file
main_switch.c/h	Mode switching program file
main.c	Main routine program file

Table 4.3.1-2 Middle layer files

File name	Functions
lcd_font.h	LCD display font definition file
mid_communication.c/h	Communication interface program file
mid_lcd.c/h	LCD interface program file
mid_switch.c/h	Switch interface program file
mid_timer.c/h	Timer interface program file

4.3.2. File structure(src/driver/)

The driver folder contains the S1C17M02/M03 peripheral circuit driver files.

Table 4.3.2-1 Driver layer files

File name	Functions
boot.c	Device startup initialization program file
c17_clg.c/.h	CLG driver program file
c17_dsadc16.c/.h	DMM controller driver program file
c17_eeprom.c/.h	EEPROMC driver program file
c17_i2c.c/.h	I2C driver program file
c17_init_config.h	C17 driver configuration file
c17_lcd4b.c/.h	LCD4B driver program file
c17_misc.c/.h	MISC driver program file
c17_port.c/.h	PPORT driver program file
c17_pwg.c/.h	PWG driver program file
c17_snda.c/.h	SNDA driver program file
c17_spia_asm.s	SPI data Tx/Rx Assembly file
c17_spia.c/.h	SPI driver program file
c17_svd4.c/.h	SVD4 driver program file
c17_t16.c/.h	T16 driver program file
c17_uart3.c/.h	UART3 driver program file
c17_wdt2.c/.h	WDT2 driver program file
crt0.h	C runtime file
libfloat.c/.h	Numeric to string conversion program file
strnum.c/.h	String creation and concatenation program file

4.3.3. File structure(inc/)

The inc folder contains the S1C17M02/M03 peripheral circuit register definition files.

Table 4.3.3-1 Files list in inc folder

File name	Functions
reg/	S1C17M02/M03 peripheral circuit register definition file folder
c17_mcu_select.h	MCU selection header file
c17m02_reg.h	S1C17M02 peripheral circuit register definition file
c17m03_reg.h	S1C17M03 peripheral circuit register definition file

Software description

4.3.4. Configuration of MCU to be used

In this software, the MCU to be operated can be specified by enabling either one of the following macro descriptions in "inc/c17_mcu_select.h".

```
#define C17_MCUSEL_M02      Enable if operate with S1C17M02
#define C17_MCUSEL_M03      Enable if operate with S1C17M03
```

If the MCU to be used is designated as S1C17M02, some functions will not be available because S1C17M03 uses peripheral functions that are not available in S1C17M02. The following is a list of software functions and Flash resources that can be used with each MCU selects.

Table 4.3.4-1 Available software functions

Function blocks	S1C17M02	S1C17M03
Application Layer	Not supported	✓
Middle Layer	Not supported	✓
Driver Layer	✓	✓

Table 4.3.4-2 Flash resources

Function blocks	S1C17M02 [byte]	S1C17M03 [byte]
Application Layer	-	6,340
Middle Layer	-	2,010
Driver Layer	10,816	14,684
Standard library	-	10,932

4.3.5. Configuration of Peripheral circuit to be used

The software allows configuring the peripheral circuits to be used by writing macros in "src/c17_init_config.h." By enabling the macros defined in the form of C17_PE_XX, the peripheral circuit functions corresponding to the macro names can be used.

Table 4.3.5-1 Peripheral circuit function enable macro

Macro names	Functions
C17 PE DSADC16	DMM controller driver
C17 PE EEPROMC	EEPROMC driver
C17 PE I2C MASTER	Master mode of I2C driver
C17 PE I2C SLAVE	Slave mode of I2C driver
C17 PE LCD4B	LCD4B driver
C17 PE PORT	PPORT driver
C17 PE PWG	PWG driver
C17 PE SNDA	SNDA driver
C17 PE SPIA SLAVE	Master mode of SPIA driver
C17 PE SPIA MASTER	Slave mode of SPIA driver
C17 PE SVD4	SVD4 driver
C17 PE T16	T16 driver
C17 PE UART3	UART3 driver
C17 PE WDT2	WDT2 driver

4.3.6. Software modules description

For each module in the file, the function name and its function are described, focusing on the functions that make up the DMM.

4.3.6.1. main_battery.c

Function name	Functions
initBattery()	Initializes functions related to battery monitoring
SvdIntHandler()	Interrupt handler for the supply voltage detection circuit. Stops all circuits other than the peripheral circuits required for LCD and displays a low battery on the LCD.
stopPeripheralExceptDispOnLcd()	Stops all circuits other than the peripheral circuits required for LCD
dispLowBattOnLcd()	Displays a low battery on the LCD

4.3.6.2. main_communication.c

Function/global variable name	Functions
runComMode()	The main routine that performs the functions of the communication mode
updateComState()	Manages communication status
setComStartDaraToBuf()	Stores the start data for communication in the transmit data buffer
setMeasDataToBuf()	Stores the measurement data in the transmit data buffer
setComEndDataToBuf()	Stores the end data for communication in the transmit data buffer
sentCount	Transmitted data counter

4.3.6.3. main_lcd.c

Function name	Functions
dispModeNameOnLcd()	Displays mode name and measurement mode name on LCD
dispResultOnLcd()	Displays measurement result on LCD

4.3.6.4. main_measurement.c

Function/global variable name	Functions
runMeasMode()	The main routine that performs the function of the measurement mode
stopMeasurement()	Stops measurement
startMeasurement()	Starts measurement
result	Measured value variable after calculation

4.3.6.5. main_switch.c

Function name	Functions
switchMeasMode()	Performs measurement mode transitions
switchMeasRange()	Performs measurement range transitions
switchPeakHold()	Performs peak-hold configuration transitions

Software description

4.3.6.6. main.c

Function name	Functions
main()	The main routine that realizes the DMM function
initPeripheral()	Initializes all peripheral circuits and interfaces to be used
setClg()	Sets the clock generator settings
checkLcdDisp()	Turns on all segments of the LCD

4.3.6.7. mid_communication.c

Function/global variable name	Functions
initCommunication()	Initializes the communication interface
startCommunication()	Starts operation of the communication interface
stopCommunication()	Stops operation of the communication interface
initBuf()	Initializes the transmit data buffer
sendTxDataToBuf()	Stores data in the transmit data buffer
sendTxBuf()	Transmits the contents of the transmit data buffer
c17sendSpiaData()	Transmits data via SPI communication
comMode	Current communication mode state variable

4.3.6.8. mid_lcd.c

Function name	Functions
putStrOnLcd()	Displays any string on the LCD
putChrOnLcd()	Displays any character on the LCD
putQuoteOnLcd()	Controls the display of “ ” at any position on the LCD
getLcdVramAddr()	Gets the VRAM address of any LCD segment

4.3.6.9. mid_switch.c

Function/global variable name	Functions
initSwitch()	Initializes the switch interface
updateSwitch()	Manages switch state transitions
getTactileSwitchInput()	Gets all tactile switch inputs
getRotarySwitchInput()	Gets rotary switch input
transition	Switch state transition structure variable

4.3.6.10. mid_timer.c

Function/global variable name	Functions
initTimer()	Initializes the timer interface
startTimer()	Starts counting for the specified timer
stopTimer()	Stops and resets counting for the specified timer
T16Ch0IntHandler()	T16Ch0 interrupt handler that generates time
T16Ch1IntHandler()	T16Ch1 interrupt handler that generates time
modeNameDispFlg	Timer flag variable for mode name display
timeOutFlg	Timeout timer flag variable
swPollingFlg	Timer flag variable for switch polling
lcdDispRefreshFlg	Timer flag variable for LCD display update

4.3.6.11. c17_dsadc16.c

Function/global variable name	Functions
c17calcMeasValue()	Calculates the measured value
c17calcCapasitance()	Calculates the capacitance value
c17intT16bCh1()	Interrupt handler for T16B_DMM Ch1. Counts the values and calculates the frequency required for frequency calculation.
c17intT16bCh2()	Interrupt handler for T16B_DMM Ch2. Counts the values required for frequency calculation.
c17dsadc16AdcEndFlg	A/D conversion end flag variable
c17dsadc16OverWriteFlg	Over write flag variable
t16bCh1IntCapFlg	T16B_DMM Ch1 capture flag variable
frequency	Calculated frequency value variable
meas	Measurement setting structure variable
acPeakMax	Maximum value peak-hold variable
acPeakMin	Minimum value peak-hold variable

5. Software operation description

This software includes functions to control SVT17M03 to realize the DMM function.

The following table shows the number of the Refer to "Figure 4.2-1: Software Operation Conceptual Diagram" for a description of the operations included in the software.

Main software functions:

- Control function for DMM mode operation
- Measurement calculation function
- Serial communication function of measured values

5.1. System initialization

This process collectively initializes the peripheral circuit functions and interfaces required for DMM operation, including the clock settings for operating the MCU. The following are the setting values for various peripheral circuits in this software, which can be changed to any desired value from `c17_init_config.h` in the driver. Only the peripheral circuits used in this software are listed.

Table 5.1-1 Peripheral circuit setting values (1)

Peripheral circuit	Setting items	Configurations
CLG	System clock	OSC3
	Frequency	3.2MHz
DSADC16	Interrupt level	3
	Clock source	OSC3
	Clock frequency division ratio	1:4
LCD4B	Interrupt level	0
	Clock source	OSC1
	Clock frequency division ratio	1:1
PPORT(GPIO)	Interrupt level	0
P07	Input / Output	Output
	Chattering prevention filter	Disable
	Pull-up/down resistor	Disable
P40, P41, P42, P43, P44, P45, P46	Input / Output	Input
	Chattering prevention filter	Disable
	Pull-up/down resistor	Pull-up enable
SNDA	Interrupt level	0
	Clock source	OSC1
	Clock frequency division ratio	1:1
SPI	Interrupt level	0
	Master/Slave	Slave
	Input pin pull-up/down	Disable
	Clock phase/polarity	Mode 3
	Data sequence	MSB first
	Data length	8bit
SVD4	Interrupt level	3
T16 Ch.0	Clock source	OSC1
	Clock frequency division ratio	1:256
	Mode	Repeat mode
	Reload value	127
T16 Ch.1	Clock source	OSC3
	Clock frequency division ratio	1:128
	Mode	Repeat mode
	Reload value	1249

Software operation description

Table 5.1-2 Peripheral circuit setting values (2)

Peripheral circuit	Setting items	Configurations
T16B_DMM Ch.0	Interrupt level	0
	Clock source	OSC1
	Clock frequency division ratio	1:1
	Mode	Repeat mode
T16B_DMM Ch.1	Interrupt level	6
	Clock source	EXCL0
	Clock frequency division ratio	1:1
	Mode	Repeat mode
T16B_DMM Ch.2	Interrupt level	0
	Clock source	OSC1
	Clock frequency division ratio	1:1
	Mode	Repeat mode
UART	Interrupt level	0
	Clock source	OSC3
	Clock frequency division ratio	1:1
	Parity	None
	Data length	8 bit
	Baudrate	230400
	Flow control	None

5.2. Timer control interface

This software uses timers throughout the process to generate time, so T16 Ch.0 and T16 Ch.1 are used to generate four timers: "mode name display timer," "timeout timer," "switch polling scan timer," and "LCD display switching timer.

Table 5.2-1 Timer settings

Name	Peripheral circuit	Period
Mode name display timer	T16 Ch.0	1s
Timeout timer	T16 Ch.0	3s
Switch polling scan timer	T16 Ch.1	50ms
LCD display switching timer	T16 Ch.1	500ms

5.3. Measurement mode

The DMM controller is activated and the measurement process is performed. The operation in this mode depends on the measurement mode currently set in the DMM controller. The operation flow in this mode is as follows.

Table 5.3-1 Measurement mode operations

Measurement mode	Operation types
DC voltage	(1)
AC voltage	(1)
DC current	(1)
AC current	(1)
Resistance (CC-method)	(1)
Resistance (CV-method)	(1)
Continuity check	(1)
Capacitance (CC-method)	(2)
Capacitance (CV-method)	(2)
Diode VF	(1)
AC voltage and frequency	(2)
AC current and frequency	(2)
Internal temperature	(1)

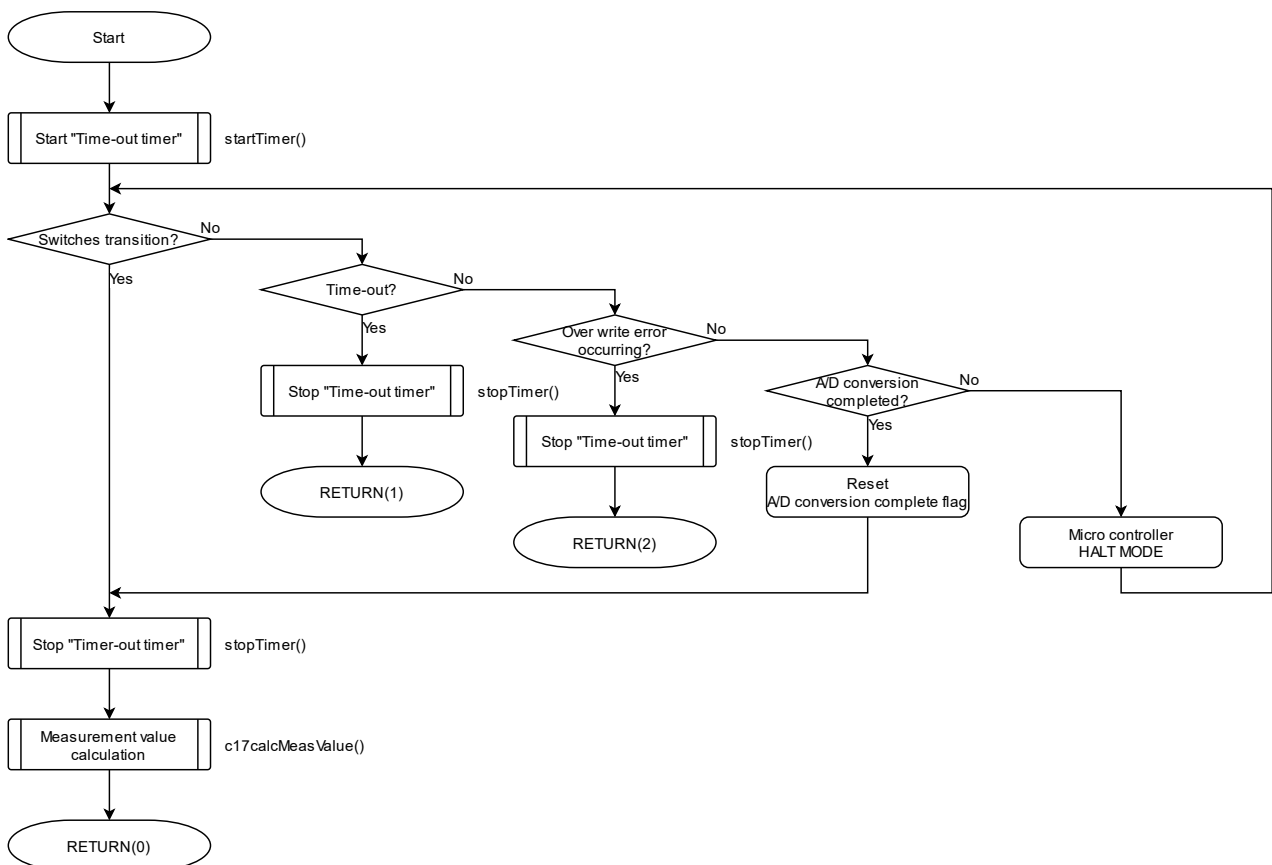


Figure 5.3-1 Measurement mode operation (1)

Software operation description

Measurement mode operation, which is classified as (1), mainly processes waiting for the completion of A/D conversion by the DMM controller. Normally, the microcontroller waits in HALT mode and returns to operation when it receives an interrupt for the completion of A/D conversion. A timeout period of 3s is provided, at which time the operation is terminated if the A/D conversion operation is not completed or an overwrite error occurs. In addition, the A/D conversion wait operation is interrupted when a setting change due to a switch transition is detected. However, the switch to be monitored differs for each measurement mode because the response to communication and the response to measurement range switching and peak hold switching differs depending on the measurement mode.

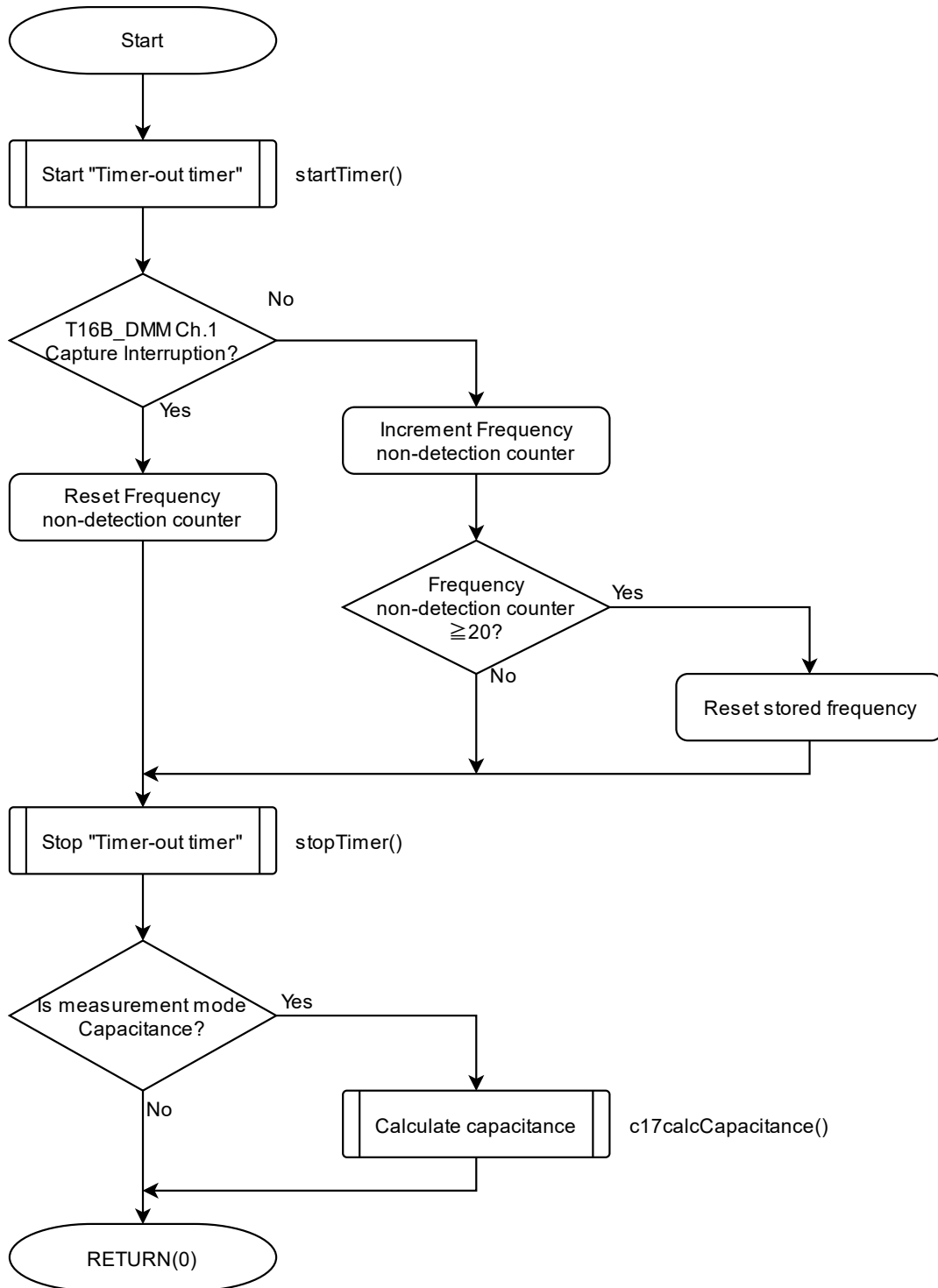


Figure 5.3-2 Measurement mode operation (2)

The measurement mode operation, which is classified as (2), mainly performs operations related to the frequency measurement process. The T16B_DMM Ch.1 capture interrupt is linked to the measurement signal input. Therefore, the case where the interrupt does not occur is the case where there is no input signal to be measured. When this state of no input signal occurs 20 times in a row, the calculation frequency stored so far is reset to 0. Finally, if the measurement mode is capacitance, the capacitance value is calculated.

5.3.1. Measurement mode switching

When a rotary switch transition is detected at initial startup and during measurement or communication mode, measurement is interrupted if measurement is in progress and the DMM controller is set to the measurement mode corresponding to the rotary switch value.

5.3.2. Measurement range switching

When the tactile switch (SW4) is pressed during the measurement mode, the measurement range switching process is performed if the measurement mode being executed corresponds to the measurement range switching. When the measurement mode is capacitance (CC method), the T16B_DMM Ch.0 comparator counter value is different only for the 1000uF range, so the setting is changed here. The measurement range switching process flow in this software is as follows.

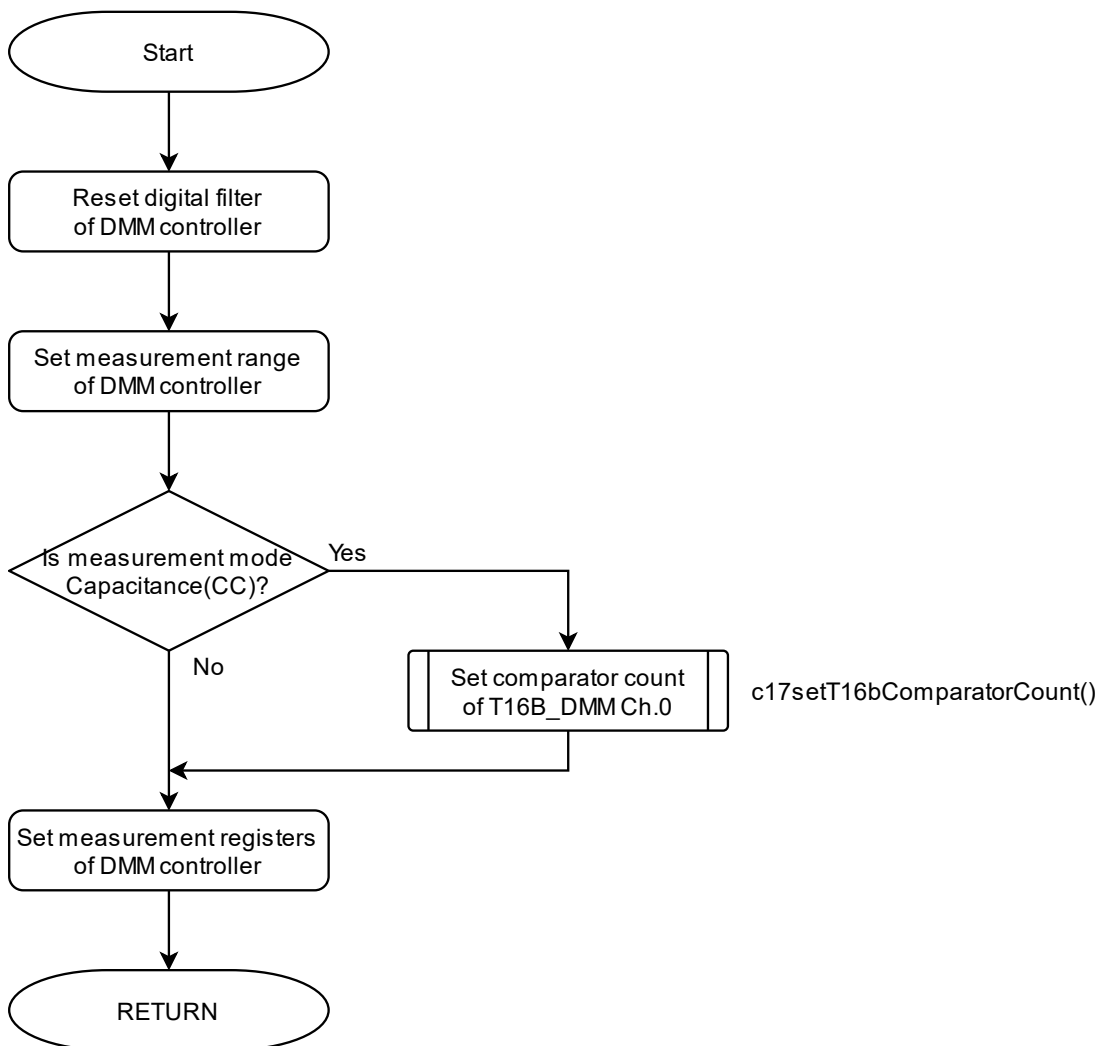


Figure 5.3.2-1 Measurement range switching operation

5.3.3. Peak-hold switching

When the tactile switch (SW3) is pressed during the measurement mode, the peak hold switching process is performed if the measurement mode being executed supports the peak hold function. In addition to the peak hold setting of the DMM controller, this section also initializes variables necessary when peak hold is realized by software processing, as described later.

5.4. Communication mode

When the tactile switch (SW2) is pressed during the measurement mode, the communication mode is processed if the measurement mode being executed supports data transmission via communication. Once the communication mode is started, the processing is performed according to the following processing flow. In the communication status update process in the flow, the communication status is updated according to the following state transition diagram. At the same time, processing of communication termination by pressing the tact switch (SW2) during the communication mode is also performed here.

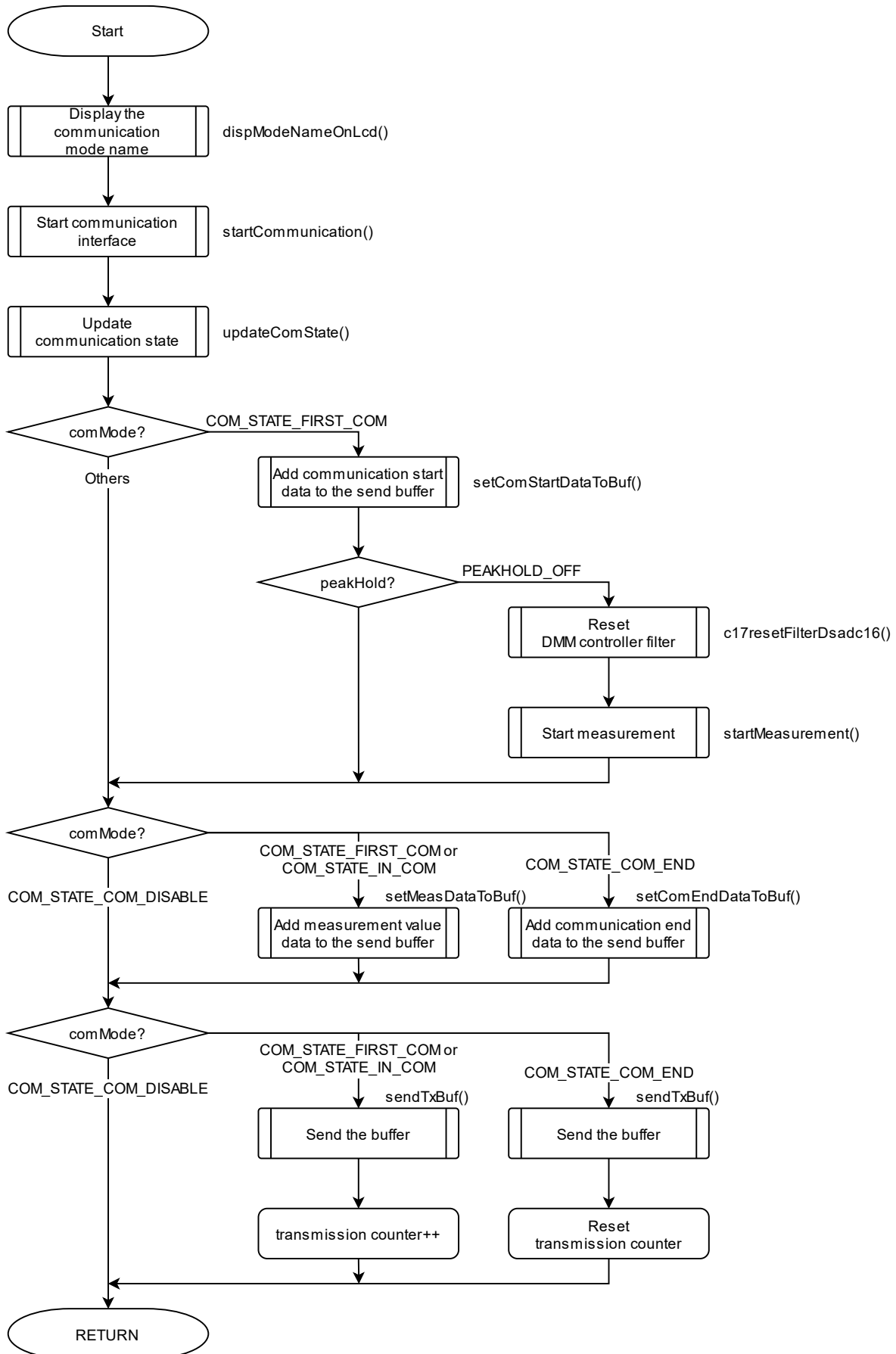


Figure 5.4-1 Communication mode operation

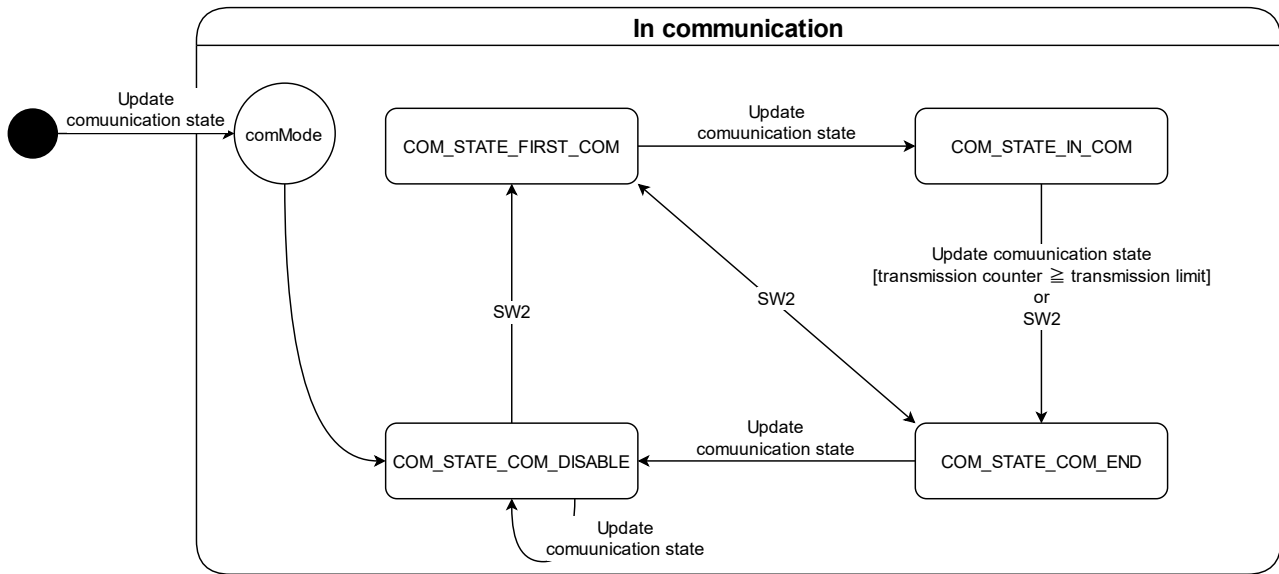


Figure 5.4-2 Communication mode state transition

5.5. Calculation function of measurement data

The S1C17M03 on SVT17M03 can measure various circuit parameters by properly configuring the DMM controller and 16-bit PWM timer for DMM. This software performs conversion operations to measurement units such as voltage [V], frequency [Hz], and capacitance [F] based on the A/D conversion values and timer count values output from the circuit.

In the measurement mode that can be measured by the DMM controller, the conversion of measurement units is processed in the following three ways. Note that no special calculation is performed in this software to use the linkage function between the buzzer output control of the MCU and the DMM controller in the continuity check mode. Also, no calculation is performed for internal temperature measurement because this software does not derive the measured temperature. The following is an explanation of each conversion method. However, the explanation of “(3) Calculation using frequency” is omitted because this software does not perform any special processing.

Table 5.5-1 Method of measured value calculation

Measurement mode	Conversion method
DC voltage	(1) Calculation from A/D conversion value
AC voltage	(1) Calculation from A/D conversion value
DC current	(1) Calculation from A/D conversion value
AC current	(1) Calculation from A/D conversion value
Resistance (CC-method)	(1) Calculation from A/D conversion value
Resistance (CV-method)	(1) Calculation from A/D conversion value
Continuity check	None
Capacitance (CC-method)	(3) Frequency-based calculation
Capacitance (CV-method)	(3) Frequency-based calculation
Diode VF	(1) Calculation from A/D conversion value
AC voltage and frequency	(2) Calculation using T16B DMM PWM Timer
AC current and frequency	(2) Calculation using T16B DMM PWM Timer
Internal temperature	None

5.5.1. Calculation from A/D conversion value

In this method, A/D conversion values acquired by the DMM controller can be converted to measurement units by multiplying the A/D conversion values by numerical values specific to each measurement mode and measurement range. The operation is expressed by the following equation using the conversion coefficient K shown on the next page.

$$\text{Measurement value} = \text{A/D conversion value} \times K \quad (\text{Eq. 5.5.1.1})$$

Table 5.5.1-1 Method of measured value calculation

Measurement mode	Measurement range	Coefficient K
DC voltage	600mV	9.1552734e-5
	6V	9.1635214e-4
	60V	9.1561799e-3
	600V	9.1644287e-2
	1000V	8.4518667e-2
AC voltage	600mV	9.1552734e-5
	6V	9.1635214e-4
	60V	9.1561799e-3
	600V	9.1644287e-2
	1000V	8.4518667e-2
DC current	600uA	8.3665198e-8
	6mA	9.0637298e-7
	60mA	8.3673482e-6
	600mA	9.0646272e-5
	6A	8.4510216e-4
	10A	9.1552734e-3
AC current	600uA	8.3665198e-8
	6mA	9.0637298e-7
	60mA	8.3673482e-6
	600mA	9.0646272e-5
	6A	8.4510216e-4
	10A	9.1552734e-3
Resistance (CC-method)	600Ω	5.493164e-2
	6kΩ	4.577637e-1
	60kΩ	4.577637
	600kΩ	4.5771835e1
	6MΩ	4.5735164e2
	60MΩ	4.5776367e3
Resistance (CV-method)	600Ω	5.493164e-2
	6kΩ	4.577637e-1
	60kΩ	4.577637
Diode VF	-	2.2888184e-4

Software operation description

5.5.2. Software processing of peak-hold function

In this method, software processing is used to replace the peak hold function of the DMM controller in some register settings. The register setting conditions and processing flow for software processing of the peak hold function are as follows. After processing, the peak hold function is realized by using the “previous measurement result register value” saved in the flow to calculate the measured value.

Table 5.5.2-1 Conditions for software processing of peak-hold function

DSADC16CTL.FUNCSEL	DSADC16CONF.TRUERMS_ON
1 (AC voltage)	1
3 (AC current)	1

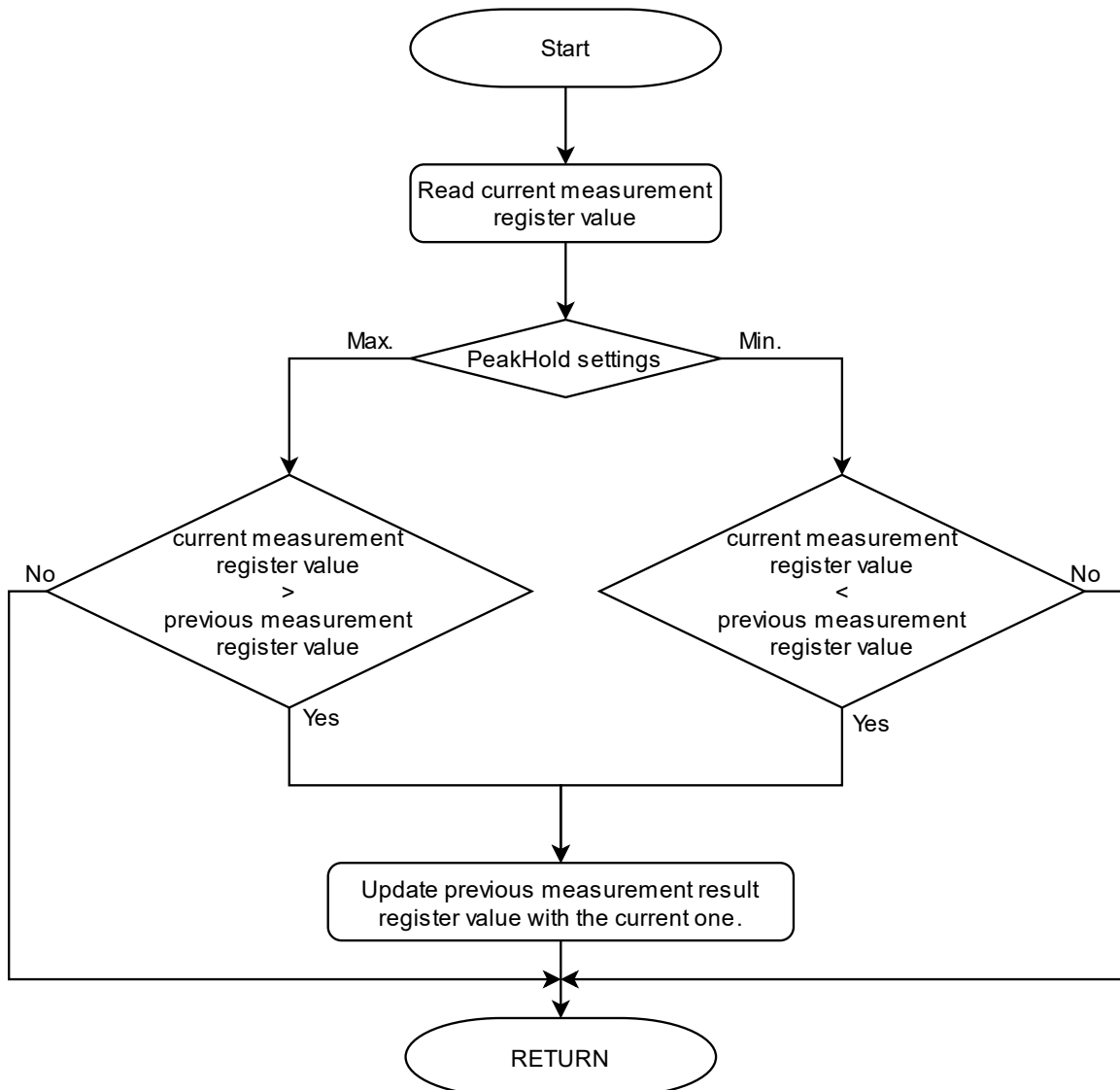


Figure 5.5.2-1 Software processing of peak-hold function

5.5.3. Calculation using T16B_DMM PWM Timer

The frequency is measured by measuring the square wave (input pulse to be measured for frequency) output from the DMM controller's WINCMP using three channels of 16-bit PWM timers for DMM and converting it to a value equivalent to the frequency. For details on the role and settings of the PWM timers used for frequency measurement, please refer to the “S1C17M02/M03 Technical Manual”.

When the T16B_DMM setting is made as described in the Technical Manual, the frequency can be measured in the configuration shown below. In this software, frequency calculation is handled in the CMPCAP0 interrupt handler of T16B_DMM Ch.1 to enable immediate frequency calculation.

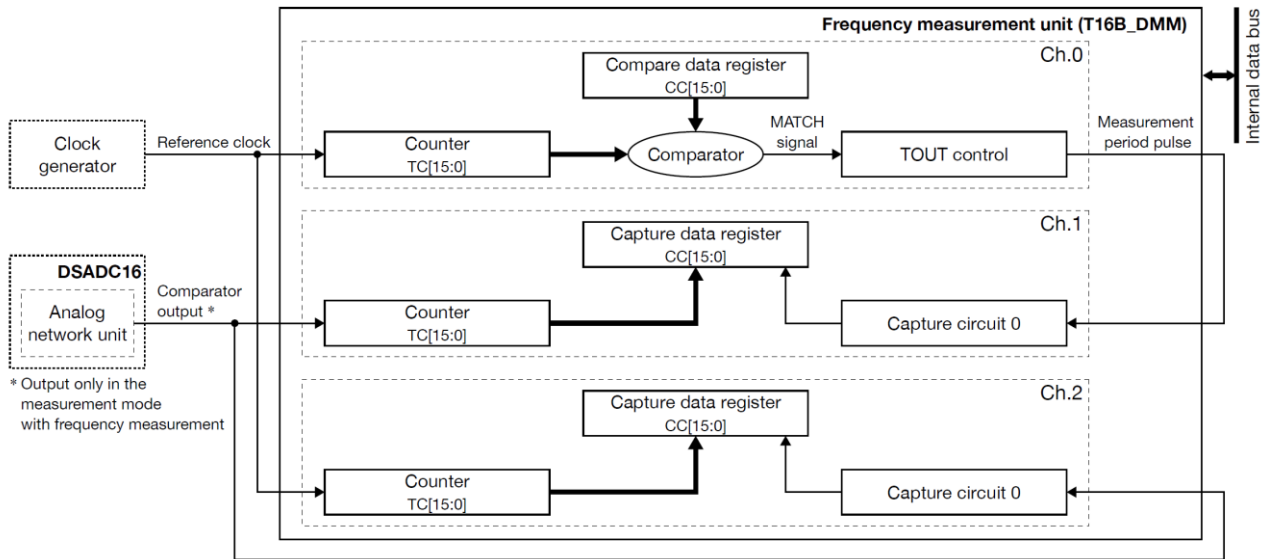


Figure 5.5.3-1 Frequency measurement unit block diagram (excerpt from Technical Manual)

Software operation description

5.5.3.1. Frequency calculation example

Frequency calculation operations are performed as described in the technical manual. As an example, this is the measurement of a 5 Hz frequency input signal.

When a 5-Hz square wave signal is input, the frequency measurement unit captures counts on each channel of the timer as shown below and calculates the frequency in the following steps. Since the count value of each count becomes 0 when it overflows, this software uses the CNTMAX interrupt in Ch.1 and Ch.2 to count the number of times it overflows to calculate the cumulative count capture value during the measurement period.

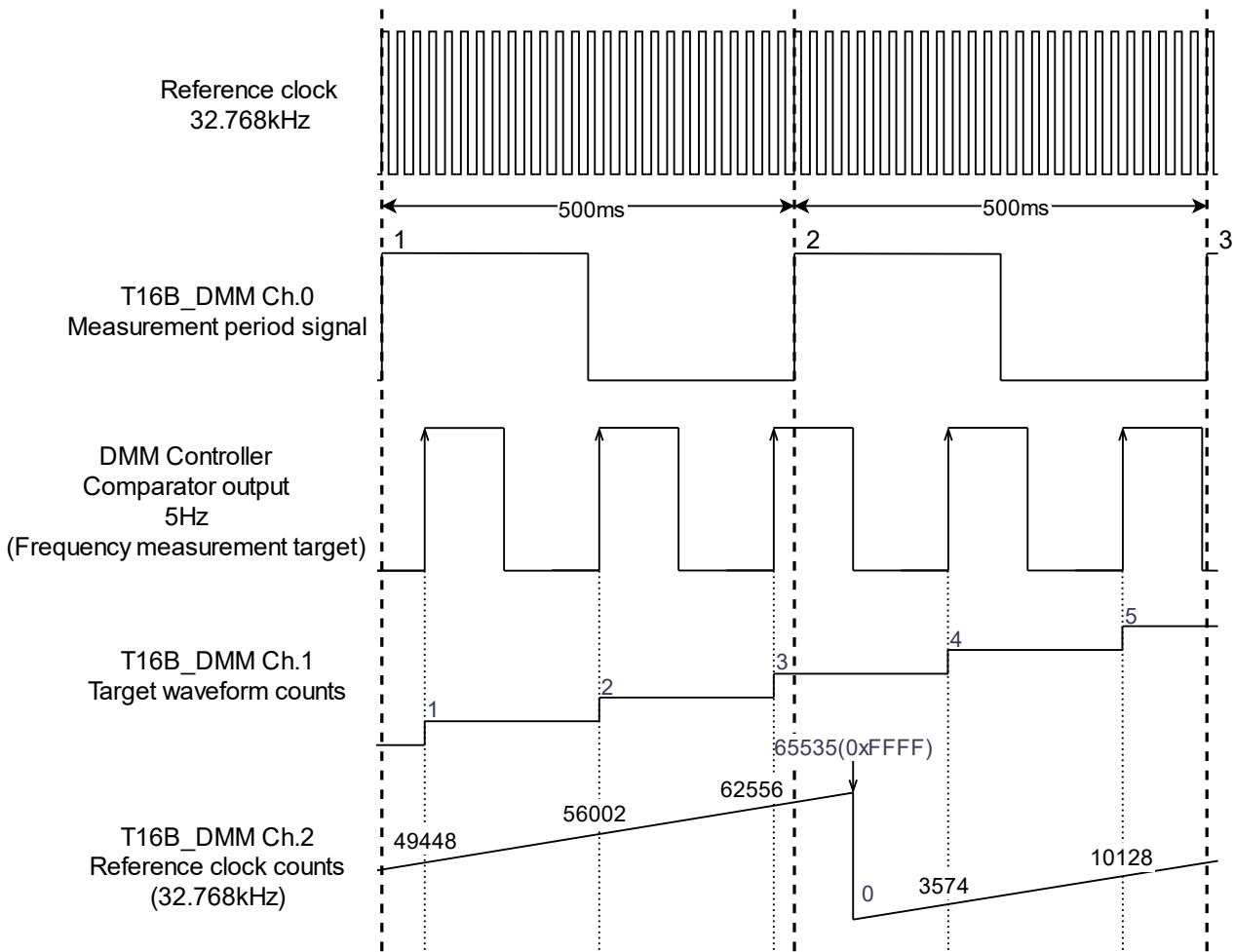


Figure 5.5.3.1-1 Capture value of T16B_DMM each Channel

• **Frequency calculation equation**

T16B_DMM Ch.1 1st capture value: n_{IN1} Reference clock frequency (32,768Hz): f_R
 T16B_DMM Ch.1 2nd capture value: n_{IN2} Measurement period ($2 \times T16B0CCR0$ register value): n_R
 T16B_DMM Ch.2 1st capture value: n_{E1}
 T16B_DMM Ch.2 2nd capture value: n_{E2}

When $n_{IN1} - n_{IN2} \geq 4000$:

$$F[Hz] = \frac{f_R \times (n_{IN2} - n_{IN1})}{n_R} \quad (\text{Technical Manual Eq. 14.1})$$

When $n_{IN1} - n_{IN2} < 4000$:

$$F[Hz] = \frac{f_R \times (n_{IN2} - n_{IN1})}{n_{E2} - n_{E1}} \quad (\text{Technical Manual Eq. 14.2})$$

1. At the second rise of the measurement period signal of T16B_DMM Ch.0, that is, when the T16B_DMM Ch.1 CMPCAP0 interrupt occurs, the T16B_DMM Ch.1 measurement waveform count capture value ($n_{IN1} = 3$) and T16B_DMM Ch.2 reference clock count capture value ($n_{E1} = 62556$) is saved.
2. At the rise of the next T16B_DMM Ch.0 measurement period signal (the third time), similarly, save the T16B_DMM Ch.1 measurement waveform count capture value ($n_{IN1} = 5$) and the T16B_DMM Ch.2 reference clock count capture value n_{E2} . Now, the capture value of T16B_DMM Ch.2 is $n_{E2} = 10128 + 65536 \times 1 = 75664$ because it has gone through count overflow once.
3. Calculate the difference between n_{IN}
 $n_{IN2} - n_{IN1} = 5 - 3 = 2$
4. Since $n_{IN2} - n_{IN1} = 2 < 4000$, the frequency is calculated according to the Technical Manual Eq.14.2.

$$F[Hz] = \frac{f_R \times (n_{IN2} - n_{IN1})}{n_{E2} - n_{E1}} = \frac{32768 \times (5 - 3)}{75664 - 62556} \approx 4.999695$$

Revision History

Revision History

Attachment-1

Rev. No.	Date	Page	Category	Contents
Rev 1.0	2022/3/17	All	new	new

America

Epson America, Inc.

Headquarter:
3131 Katella Ave.
Los Alamitos, CA 90720, USA
Phone: +1-800-463-7766

San Jose Office:
2860 Zanker Road Suite 204
San Jose, CA 95134, USA
Phone: +1-800-463-7766

Europe

Epson Europe Electronics GmbH

Riesstrasse 15, 80992 Munich,
Germany
Phone: +49-89-14005-0 FAX: +49-89-14005-110

Asia

Epson (China) Co., Ltd.

4th Floor, Tower 1 of China Central Place, 81 Jianguo Road, Chaoyang
District, Beijing 100025 China
Phone: +86-10-8522-1199 FAX: +86-10-8522-1120

Shanghai Branch

Room 601-603, Building A One East, No.325 East Longhua Road,
Shanghai 200023, China
Phone: +86-21-5330-4888 FAX: +86-21-5423-4677

Shenzhen Branch

Room 804-805, 8 Floor, Tower 2, Ali Center, No.3331
Keyuan South RD(Shenzhen bay), Nanshan District, Shenzhen
518054, China
Phone: +86-755-3299-0588 FAX: +86-755-3299-0560

Epson Taiwan Technology & Trading Ltd.

15F, No.100, Songren Rd, Sinyi Dist, Taipei City 110. Taiwan
Phone: +886-2-8786-6688

Epson Singapore Pte., Ltd.

438B Alexandra Road,
Block B Alexandra TechnoPark, #04-01/04, Singapore 119968
Phone: +65-6586-5500 FAX: +65-6271-7066

Epson Korea Co.,Ltd

10F Posco Tower Yeoksam, Teheranro 134 Gangnam-gu,
Seoul, 06235, Korea
Phone: +82-2-3420-6695

Seiko Epson Corp. Sales & Marketing Division

MD Sales & Marketing Department

29th Floor, JR Shinjuku Miraina Tower, 4-1-6 Shinjuku,
Shinjuku-ku, Tokyo 160-8801, Japan